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DISCUSSION OF ATCHAFALAYA DIVERSION AND ITS EFFECT ON THE MISSISSIPPI RIVER

(*Published in March, 1950*)

By E. F. Salisbury, James F. Halsey, Jere W. Higgs, Jr., and Leo M. Odom

WATERWAYS DIVISION

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DISCUSSION

E. F. SALISBURY,[19] M. ASCE.—Briefly stated, the author's contentions are that:

1. Unrestricted below-bank diversion creates a problem different from that of controlled over-bank diversion.
2. Discharge measurements prior to 1913 cannot be used for comparative purposes without qualification, and data collected about 1940 must be carefully evaluated because of changes in the procedure of taking measurements.
3. A study of the stage-discharge relationship does not indicate any progressive changes in the discharge capacity of the Mississippi River below Old River in Louisiana.
4. Experiments that have been made on movable bed models of bifurcated channels give a clue as to why the normal tendency of an alluvial stream toward adjustment of its capacity to its flow requirements has not been found to operate in this case.

The writer's thoughts are not at great variance with those of the author, and his discussion will cover these four points in order.

Unrestricted diversion of flow from the Mississippi River into the Atchafalaya River at all stages (such as at Red River Landing in Louisiana) reduces the velocity in the main channel downstream from the point of diversion as compared with velocities upstream. As the volume of water diverted increases, there is a corresponding increase in the difference between the upstream and the downstream velocities. The natural result is that some of the silt load is deposited downstream, thus reducing the cross-sectional area of the channel. The direct effect of the unrestricted diversion is to increase the slope of the main river at the point of diversion, as evidenced by an increase in gage height for the same discharge.

When the flow is diverted at stages that overtop the banks (controlled or uncontrolled), the downstream reduction in cross-sectional area is not noticeable. This fact has been demonstrated at a point upstream from Arkansas City, Ark. (Cypress Creek Gap), where uncontrolled over-bank diversion occurred for a number of years. Since 1921 the levee line has been closed at this point and floodwaters have been confined except at infrequent intervals when they have been released through crevasses. The over-bank flow prior to 1921 has had no noticeable effect on the Arkansas City gage, the discharge remaining constant for the period from 1890 to 1929. (Cutoffs made in this reach of the river subsequent to this period have radically changed the gage and discharge relationship.)

NOTE.—This paper by Leo M. Odom was published in March, 1950. The numbering of footnotes, tables, and illustrations in this Separate is a continuation of the consecutive numbering used in the original paper.

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At Bonnet Carré spillway, about 24 miles upstream from the New Orleans (La.) gage station at Carrollton, the flow has been diverted, over bank, three times; and this controlled floodwater escape had no noticeable effect on the New Orleans gage.

Although the technique of measuring the discharge of rivers has improved, the effect on studies of the Mississippi River, using both old and new gage readings and discharges, is problematical. Nevertheless, the result of unrestricted diversion at Red River Landing is apparent by either method of analysis.

By studying records of meter readings,[6] about 1935, the writer found that, between the periods from 1867 to 1886 and from 1912 to 1933, the average flood peaks at Red River Landing were increased 7.3 ft. This was the result of raising and strengthening the levees on the Mississippi, thus confining increasingly larger quantities of water in the main river and causing correspondingly larger diversion of flow to the Atchafalaya River. Below the point of diversion, the main river adjusted itself progressively with increased flood heights and consequent increase in diversion—the river channel being partly closed by a silt deposited dam. By an analysis of discharge measurements obtained with older techniques, it was apparent that this diversion had increased the slope and thus raised the gage 6.9 ft. in order to permit the discharge to remain the same as it had been since 1882. It is interesting, therefore, to note how very closely the analysis based on recent measurements agrees with that obtained by the older data.

TABLE 7.—STUDY OF 1945 GAGE RECORD, RED RIVER LANDING, IN LOUISIANA

Date[a]	Gage height, in feet	Mean velocity, in ft per sec	Discharge,[a] in thousands of cu ft per sec	Gage height adjusted to 1,100,000 cu ft per sec
(1)	(2)	(3)	(4)	(5)
March 9, 1945	41.4	5.34	1,073	42.2
March 12, 1945	43.0	5.45	1,125	42.3
May 18, 1945	49.8	4.93	1,130	48.9
May 19, 1945	49.0	5.02	1,126	48.3
May 21, 1945	48.2	5.00	1,105	48.1

[a] Maximum discharge on April 16, 1945, was 1,515,000 cu ft per sec at gage of 55.7 ft. Bonnet Carré spillway was in operation from March 24 to May 17, 1945.

The flood of 1945 provides an excellent example, selecting a discharge of 1,100,000 cu ft per sec to compute the heights at the gaging station. In Table 7, Col. 4, discharge readings within 30,000 cu ft per sec of the selected discharge are adjusted to that discharge (1,100,000 cu ft per sec) in Col. 5. During the early stages of the 1945 flood (March 9) the selected discharge passed at a low gage height of 42.2 ft, as the result of corrective dredging, in 1938, at Smithland, La. (see heading, "Dredging Below the Mouth of the Old River"). As the flood height increased, larger volumes passed into the Atchafalaya River and

[6] "Influence of Diversion on the Mississippi and Atchafalaya Rivers," by E. F. Salisbury, *Transactions*, ASCE, Vol. 102, 1937, p. 75.

the gage readings in the main river increased correspondingly to reflect the existence of a constant remaining discharge.

The variation of 6.7 ft for a similar volume of water during the 1945 flood compares with a difference of 6.9 ft computed some years ago for the period from 1882 to 1933. In the earlier study, the discharge data indicated that the increase had been progressive. Analysis of the 1945 flood shows that the increase in the slope of the main river, below the point of diversion, occurred during the same flood—a result that may or may not have been caused by the corrective dredging at Smithland. As stated by Mr. Odom, the Atchafalaya River was dredged extensively between 1932 and 1941, and a new outlet was constructed at Wax Lake.

The treatment of the silt load by a silt-bearing stream is evidence of the powerful capacity of such a river to adjust itself to changed conditions. The result of this adjustment can be overcome or delayed by artificial methods, such as dredging. The changes in the slope of the Atchafalaya River, caused by diversions in the two periods from 1882 to 1923 and from 1933 to 1945, cannot be compared because of the new outlet at Wax Lake and the aforementioned dredging in the main channel.

Loss in the cross-sectional area at Red River Landing during the same flood and when maximum diversion is occurring was well illustrated during the high water of 1929 and also during the high water of 1945. During the 1929 flood the deposition of silt below the point of diversion restricted the cross-sectional area to the extent of holding it to the same area during the last 5-ft rise in flood height as follows:

Gage, in feet	Area, in square feet
47.4	234,000
48.8	234,000
49.8	236,000
51.1	230,000
52.2	230,000
52.4	232,000

The loss in cross-sectional area during the 1945 flood, shown subsequently, followed closely that of 1929 although corrective dredging had been previously carried out at Smithland:

Gage, in feet	Area, in square feet
50.3	236,500
52.4	236,700
55.8	227,800
56.4	245,200

From the foregoing data, the deposition of silt during the same flood is shown to act as a natural automatic valve, holding the cross section to about the same area during maximum diversion and against a rise of several feet in gage, thus producing a steeper slope during the same flood. This silt is removed during the same flood or during intervening waters. For some time the writer has

been of the opinion that when the silt load of a heavily laden stream is subjected to a major disturbance causing either a considerable increase or a considerable loss in the silt load, such as that produced by a diversion of the flow, a material increase in roughness factor is immediately produced over that customarily used for ordinary river channels. This may or may not be a contributing factor in causing a higher gage for discharging the same volume of water below the point of diversion.

By the use of mean discharges (Fig. 4), the author has endeavored to show that the capacity of the Lower Mississippi has been improving steadily since 1927. The wide fluctuation of the gage for the same volume of water (1,100,000 cu ft per sec) during the flood of 1945 shows the misleading conclusion that can be drawn from this method.

The low gage of 42.2 ft (March 9, 1945, Table 7) closely approaches the average gage of 41.3 ft for the period from 1882 to 1885. The high gage of 48.9 ft (May 18, 1945, Table 7) exceeds the average gage of 48.2 ft for the period from 1913 to 1932 and is close to the peak gage of 50.4 ft which was registered on May 5, 1913.

The mean value of high and low gages for 1945 will indicate that the mean discharge during this year is less than that for some of the other years. Such a computation should not obscure the fact that, for a present discharge as great as that from 1913 to 1932, the gage heights must still be correspondingly high.

The writer is not questioning the results of the experiments made on movable bed models of bifurcated channels, as mentioned by the author; but the disturbance to the silt load by unrestricted diversion, such as that at Red River Landing, will result in an inefficient handling of the floodwaters in the main channel below the point of diversion. This condition can be overcome by eliminating diversion below bankfull stage, thus disturbing the greater part of the silt load, to a minor extent, and destroying the river's power of adjustment. Furthermore, waters below bankfull stage, acting for 365 days, can themselves clean out any deposition of silt left after the short duration of over-bank diversion.

A regimen is thus established by which the river is working constantly to remove any deposition of silt left after short periods of over-bank diversion. As a result, the main river, at Red River Landing, would be lowered 6 ft or 7 ft at flood heights, assuming no change in the discharge; and the backwater reservoir in the Red River would reflect correspondingly beneficial results. The quality of the New Orleans water supply, at low-water stages, would also be improved. After the Morganza Floodway project has been completed, the foregoing approach to the flood control "picture" becomes inevitable. It is possible that the operation of this floodway (which is so close to the Red River Landing) may, when it is in operation during extremely high floods, regulate the velocity through the point of diversion sufficiently to eliminate most of the disturbance caused by the present uncontrolled diversion. Before the present flood control plan was put in operation by the Corps of Engineers, United States Department of the Army, the Upper Atchafalaya Basin was flooded about once every 5 years; but no flooding has occurred since 1927.

JAMES F. HALSEY,[20] Assoc. M. ASCE.—Time and patience have been required to assemble the wealth of data presented in this paper. One does not truly appreciate the time required for preparation of such a paper or the author's statement (see under the heading, "Conclusions")—

> "Today the investigator encounters an almost overwhelming amount of information; not in all cases what he would like to have, perhaps, but all of it requiring study so as to be certain that he has not neglected some vital occurrence."

—until one makes a similar study or begins preparing a discussion of such a paper. River studies are vastly different from many other types of analyses in that events at many different locations must be given a chronological order and placed in their proper position of importance before a concise picture of causes and effects is made available for a complete understanding of the particular problem.

The problem upon which Mr. Odom has focused his attention is the century old argument, "Has diversion of water from the Mississippi River into Old River and thence into the Atchafalaya River affected the carrying capacity of the Mississippi below the point of diversion?" As noted in the paper, this subject has been one of the most argumentative topics among river hydraulicians since the log raft in the Atchafalaya was removed in 1840. The literature abounds with the pros and cons of the subject as advanced by many men and Mr. Odom has presented his ideas and thoughts for further consideration and for a possible revision of some engineers' concept of the problem. The writer regrets that Mr. Odom did not see fit to draw a more concrete conclusion from the data presented. However, by reading between the lines the writer concludes that Mr. Odom firmly believes that diversion through the Atchafalaya was not responsible for the deterioration of the Mississippi River channel at, and immediately below, Red River Landing.

In support of this "between lines" conclusion the author has offered seven subconclusions. The writer agrees with each of the seven statements and proposes the following three points for further study.

1. What is the effect upon the trend lines in Figs. 4 and 6 for Red River Landing and the Simmesport (La.) gage by the addition of the data for 1947–1949?
2. Has the Lower Atchafalaya River improved its stage-discharge relationship as much as the Upper Atchafalaya River, as shown by the Simmesport gage?
3. What caused the split channel at Smithland Landing in the Mississippi River to develop? Was it due to diversion or some other cause?

As stated earlier, a complete chronological order of events is necessary for a true and complete understanding of seemingly unrelated occurrences. This problem of diversion has its origin with the initial construction of levees on the

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Mississippi. The "squeezing" of the main river into a comparatively small channel provided extra head at the latitude of Angola (La.) to assist in forcing water from the Mississippi down the Atchafalaya. As the levee system was lengthened and strengthened, the frequency of crevasses below Angola was diminished so that this extra head was available for longer periods each succeeding year. However, until the log raft in the Atchafalaya was removed, that stream acted somewhat as an orifice—that is, the extra head at Red River Landing could not change the coefficient of discharge through the Atchafalaya. Immediately after the removal of the raft improvement of the Atchafalaya began. With a continued strengthening of the levees on the Mississippi and the building of levees on the Atchafalaya the latter river had no alternative except to enlarge and convey more water to the Gulf.

In 1890[21] a discharge of 480,000 cu ft per sec was reported for Simmesport; and, discounting 35% as being due to the pull affected by the crevasses downstream, there was still a discharge of 312,000 cu ft per sec, or 2.6 times the quantity reported for 1875. Thus the rate of change in the early stages of development was much greater than the rate of change since the turn of the century. At about this time (1890), according to Fig. 4, the Mississippi River began showing higher stages for equivalent discharges. The effect of this change should be apparent at once for more "head" was provided, thus causing more flow down the Atchafalaya. Unfortunately, from a purely scientific study of physical actions, man's scope of work on these two streams continued to enlarge so that man's influence was playing the major role in the development of the Atchafalaya. Continued levee building, raising of levee lines, dredging since 1933, and the Carr Cutoff in 1944—all contributed very materially to the improvement of the carrying capacity of the Atchafalaya. The writer ventures to guess that had not these man-made works been built, the Atchafalaya would not carry more than 300,000 cu ft per sec today. (This statement is contradictory to the thoughts of the pro-diversion group and will be explained subsequently.)

Inasmuch as the writer questioned the advisability of extending the method of adjusted stages (proposed by E. W. Lane,[22] M. ASCE) over a long period of record, he made a study of the method before applying it to the Krotz Springs gaging station record. (Krotz Springs is located at mile 41.7 on the Atchafalaya.) Essentially, Mr. Lane's method assumes that, even though a general rising or falling trend in the stage-discharge relationship may exist at a gaging station, a 1-ft increment of stage at a base discharge produces the same differential of discharge over a period of years. Mr. Odom used Mr. Lane's method in the preparation of data for Figs. 4 and 6, and the writer has used it in preparing the additional data.

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[21] "The Improvement of the Lower Mississippi River for Flood Control and Navigation," by D. O. Elliott, U. S. Waterways Experiment Station, Vicksburg, Miss., 1932, p. 52.

[22] Discussion by E. W. Lane of "Influence of Diversion on the Mississippi and Atchafalaya Rivers," by E. F. Salisbury, *Transactions*, ASCE, Vol. 102, 1937, p. 109.

At a base discharge of 200,000 cu ft per sec, the discharge per foot of stage in the Atchafalaya River at Krotz Springs is as follows:

Year	Discharge
1936	14,500
1937	14,000
1938	15,000
1939	13,000
1940	13,000
1941	14,000
1942	14,000
1943	15,000
1944	14,500
1945	15,000
1946	16,000
1947	15,000
1948	16,000
1949	14,500
Average used	15,000

These data convinced the writer that Mr. Lane's method is valid and may be used in a study of a changing stage-discharge relationship for a stream. Table 8 contains data for 1947 through 1949, for the Red River Landing and Simmesport gages by which the curves in Figs. 4 and 6 can be extended. When the curves are thus plotted, it will be seen that the trend toward an increasing channel capacity for the same stage is continuing. In trying to deduce just what importance should be attached to a trend line such as Mr. Odom has drawn, the writer tried to fit several types of curves—straight line, logarithmic, and hyperbolic—to the field data. It would be possible to fit a curve to the points in Figs. 4 and 6 which, in future years, would show an increasing stage for equivalent discharges or to fit a curve that would show a flattening out of the trend lines; but the danger of extrapolation into the future from past physical data led the writer to conclude that, regardless of what he believes may happen in years to come, the only safe approach to the problem was to show what has happened and let the reader conjecture as to what will happen. Table 9 is a comparison of slopes of trend lines (slope being equal to change in stage, in feet per year) given by the author and those found by the writer in fitting a straight-line curve ($y = m\,x + b$) to the data by the least squares method.

In the case of Red River Landing, the addition of 3 years of record causes the slope of the average trend line to flatten out, thus indicating a slowing of the rate of change of capacity. Nevertheless, the stage-discharge relationship is continuing to improve. Since it is physically impossible (without crevasses or overtopping of levees) for the Lower Mississippi River to convey much more water to the Gulf of Mexico than it now does, the writer predicts a leveling off of the trend line for the Red River Landing gage so that in time the channel

capacity of the Mississippi at that point will be 950,000 cu ft per sec (between the 1880 and 1945 rating curves in Fig. 5).

With reference to the data for the Simmesport gage on the Atchafalaya the analyst is confronted with a somewhat different problem for the physical characteristics—that is, the width, depth, sinuosity, etc., of this stream were greatly altered by man during the period from 1912 to 1949. Whereas the only change in channel configuration of the Mississippi affecting the Red River Landing gage was the minor dredging at Smithland, La., millions of cubic yards of material were dredged out of the Atchafalaya. Some 85,000,000 cu yd was removed between Krotz Springs (mile 41.7) and mile 100 in Grand Lake between 1933 and 1943.[23] Also, in 1944, Carr Cutoff just above the head of Old River removed the reverse curve entry of Old River and provided a smooth curved approach for the waters of the Mississippi into Old River and thence into the Atchafalaya.

TABLE 8.—Extension of Stage Observations, Figs. 4 and 6

Year	(a) Mississippi River at Red River Landing					(b) Atchafalaya River at Simmesport, La.				
	Base discharge (cu ft per sec)	No. of measurements	Adjusted Stages			Base discharge (cu ft per sec)	No. of measurements	Adjusted Stages		
			Highest	Mean	Lowest			Highest	Mean	Lowest
(1)	(2)	(3)	(4)	(5)	(6)	(2)	(3)	(4)	(5)	(6)
1947	1,100,000	none	....	....	....	400,000	none	....	....	....
1948		none	....	....	....		3	39.35	38.39	36.97
1949		9	48.13	46.20	42.37		7	37.34	36.82	35.77
1947	1,000,000	none	....	....	....	365,000	5	38.50	37.60	36.18
1948		1	....	42.37	....		13	39.32	37.72	35.77
1949		6	45.45	43.94	41.34		4	35.93	35.02	34.37
1947	900,000	6	44.36	43.53	42.36	330,000	4	36.58	35.72	34.33
1948		19	45.59	43.43	41.23		6	37.13	35.58	34.70
1949		7	42.08	41.37	39.21		2	32.68	32.43	32.18
1947	800,000	2	39.70	39.50	39.30	300,000	10	34.30	33.14	31.88
1948		8	40.23	38.36	36.51		5	34.55	33.73	33.02
1949		4	39.27	38.00	35.33		2	30.49	30.36	30.32

With such an "assist" from mankind one naturally would expect the Atchafalaya to show the tremendous increase in channel capacity that it did. A study of Table 9 shows plainly that the greatest increase (other than the initial increase after removal of the log raft) occurred after the aforementioned dredging because the average slope of the trend lines (Table 9) for the Simmesport gage in the period after 1935 is twice as much as for the total period of 1912–1949.

One may wonder as to whether the change in channel capacity throughout the Atchafalaya was as great as the indicated change at Simmesport. A study of the Krotz Springs gage[23] and the extension of that data on a calendar year basis through 1949 indicates that the increase in channel capacity was not as great in the lower reaches as in the upper reaches. For discharges of 200,000

[23] Discussion by James F. Halsey of "Solids in Stream Flow," by Gerard H. Matthes, *Transactions*, Am. Geophysical Union, Vol. 31, Pt. 1, April, 1950, p. 284.

cu ft per sec, 300,000 cu ft per sec, and 400,000 cu ft per sec, the mean stage lowering at Krotz Springs from 1935 to 1949 was 0.342 ft per yr, or only 50% of that evinced by the Simmesport gage. This fact can mean only one thing—the lower Atchafalaya is proving to be a serious deterrent to the over-all improvement of that stream. This action will be welcomed by those who have been worried about whether, and how soon, the Atchafalaya will "capture" the Mississippi. Even if the Atchafalaya River were to continue to increase its carrying capacity at the 1935–1949 pace, as indicated by the Simmesport gage, some 180 years would be required for the "capture." It is the feeling of the writer that regardless of what structures may be built on Old River (a navigation lock and diversion control being planned) the physical make-up of the Lower Atchafalaya Basin at Morgan City, La., and Wax Lake would preclude any such capture. The situation is somewhat analogous to that of trying to put more than 1 lb of sugar into a 1-lb container—it cannot be done without spilling some of it over the top.

TABLE 9.—Comparison of Slopes of Trend Lines

(a) Mississippi River at Red River Landing			(b) Atchafalaya River at Simmesport, La.			
Discharge (cu ft per sec)	1927 to 1946 (author)	1927 to 1949 (writer)	Discharge (cu ft per sec)	1912 to 1946 (author)	1912 to 1949 (writer)	1935 to 1949 (writer)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1,100,000	−0.170	−0.210	400,000	−0.246	−0.312	−0.781
1,000,000	−0.266	−0.170	365,000	−0.253	−0.311	−0.541
900,000	−0.187	−0.031	330,000	−0.580	−0.489	−0.746
800,000	−0.177	−0.205	300,000	−0.338	−0.369	−0.696
Average	(−0.200)	(−0.154)	Average	(−0.354)	(−0.370)	(−0.691)

An engineer may spend a lifetime studying stage-discharge relationships and know every moment just what a stream is doing; but does he know why it is doing what it is? Mr. Odom has gone beyond the stage-discharge study phase in attempting to produce evidence that would explain the vagaries of the diversion of the Mississippi River flow into the Atchafalaya River. The writer believes he has done so, with a slight possible exception, and he feels that, given enough time, Mr. Odom would have uncovered the evidence the writer has that seems to point to the Raccourci Cutoff in 1848 as the cause for the declension of carrying capacity of the Mississippi at Red River Landing from 1883 to 1938.

A thorough study of hydrographic surveys for that part of the Mississippi from above Old River to below Smithland, and the writings of H. B. Ferguson,[24] M. ASCE, have convinced the writer that the Raccourci Cutoff—and not the diversion of flow into the Atchafalaya—was responsible for the decline in the carrying capacity of the Mississippi at Red River Landing. (Surveys dated 1883, 1921, 1922, 1923, and 1924 were furnished to the writer by the Mississippi River Commission.) The 1883 hydrographic survey shows a well-defined

[24] "The History of the Improvement of the Lower Mississippi, 1932–1939," Mississippi River Comm., Vicksburg, Miss., p. 16.

channel throughout the reach cited, with shallow water being present adjacent to the left descending bank at mile 296.5 AHP (above Head of Passes). (All mileage quoted has been adjusted to the 1945 datum.) A small sand bar was present there and later became part of the extended bank line when the east bank built up and out toward the west as shown by the 1895–1896 bank line survey. However, not far from the sand bar, channel depths extended to El. −80 MGL (mean Gulf level). (Mean low water is now at about +8 ft MGL.) Table 10 compares the depths throughout this reach for the years 1883 and 1921.

In the 38-year interval shown by Table 10 the overflow through what was the bed of the river prior to 1848 was causing the current to slacken and deposit some of its bed load opposite Smithland at mile 298. In this case it required more than the 10 years cited by General Ferguson to develop the split channel which is always the aftermath of a cutoff (regardless of where it occurs), for in 1921 the split channel was beginning to be quite definite and was causing the deposition upstream which eventually extended from mile

TABLE 10.—Comparison of Channel Bottom Elevations in the Mississippi River Downstream from Red River Landing; Mean Gulf Level (MGL) Datum

Mile (AHP)[a]	January, 1883	October, 1921	Footnotes
300.5	−20	−10	[a] Above Head of Passes.
299.5	−17[b]	−11	[b] Deepest on west side.
298.5	−20	−29[c]	[c] On west side, very shallow on east side.
297.5	−20[d]	−24[e]	[d] West bank noted as caving.
296.5	−80	−65	[e] In chute on west side of island, −6 on east side.

299.7 AHP to mile 296.7 AHP. It was during this period (1883 to 1921) that Mr. Lane and E. F. Salisbury,[6] M. ASCE, noted the great decrease in channel capacity of the Mississippi at Red River Landing. Regardless of where it is, however, any gaging station would reflect a decrease in channel capacity if, immediately downstream, the channel was being choked by sand bars.

The chronology of this diversion problem, as stated previously, purposefully omitted the effect of the Raccourci Cutoff so as to show that every single one of the events in the general vicinity of Red River Landing should be put in its proper niche in time. The aftereffects of this cutoff caused gage heights at Red River Landing to rise; it was decidedly not the diversion into the Atchafalaya which caused the deposition opposite Smithland and thence affected higher gage readings at Red River Landing. Without the sand bar opposite Smithland, gage heights at Red River Landing would not have been raised 7 ft from 1883 to 1928 (see Fig. 4) and this extra head would have not been made available to the Atchafalaya for its push through the tough back-swamp clays. (In a case of free discharge, a head of 7 ft provides a velocity of 21 ft per sec.) Without the extra head there would have been a less rapid development of the Atchafalaya and, furthermore, without the dredging since 1933, the Atchafalaya would be physically unable to discharge

more than about 300,000 cu ft per sec without crevasses or levee overtopping affecting the discharge.

It is felt that the field data, presented by the author and by the writer, tend to refute the theorem of Domenico Guglielmini. Mr. Guglielmini laid down his concept of flow below a diversion when field or experimental data were not to be had. Doubtless his concept of the normal stream velocity profile, as stated by Robert Manning[25]—

> "He [Guglielmini] believed that the velocities increased from the surface towards the bottom as the ordinates of a parabola, and that motion at the surface was produced by the effects of the fluid molecules imparting a velocity to those above them. In the early part of the 18th century Pitot * * * proved by actual experiment the fallacy of Guglielmini's theory."

—was the basis of his diversion theory.

Even though a few engineers may still rely on the Guglielmini theorem as an explanation of the flow phenomena occurring in the Mississippi River at Angola, the writer believes that the ideas presented by Mr. Odom will pass the acid test of time and, in due course, fully supplant the Guglielmini theorem.

JERE W. HIGGS, JR.,[26] JUN. ASCE.—Mr. Odom is to be commended for his thorough study of a subject that has received surprisingly little attention in the technical press. Certainly the diversion of water through the Atchafalaya River presents engineering problems of sufficient magnitude to warrant the most detailed study by all river engineers.

The author has presented data which indicate the trends in the development of the Atchafalaya River and the effect of the increased diversion on the Mississippi River. He has conducted his analysis (under the heading, "Effect of Diversion Into the Atchafalaya River on the Capacity of the Mississippi River Below the Old River") "* * * without reference to general laws or theories * * *."

Only by conducting the study under such conditions can it be considered truly objective. Engineers, however, must insist upon some logical explanation for natural phenomena. If no action dependent on basic physical laws may be shown, eventually, to be responsible for the observed changes in river regimen, the modern conception of engineering is in need of revision.

Data presented in the text and in Figs. 4 and 5 reveal no long-term deterioration in the channel of the Mississippi River below Old River. If it is admitted that the total flow in the Mississippi downstream from Old River has decreased an appreciable amount as the Atchafalaya has become more efficient, these data seem to be in direct contradiction to the commonly accepted theory that an alluvial river will adjust its bed to its discharge. As pointed out by the author, however, these data do not disprove the theory but serve to emphasize the importance of considering local conditions in its application.

The question of how much change has occurred in the quantity of flow passing Red River Landing immediately presents itself if an attempt is made to

[25] "On the Flow of Water in Open Channels and Pipes," by Robert Manning, *Transactions*, Institution of Civ. Engrs. of Ireland, Vol. XX, 1891, p. 161.

[26] Engr., Leo M. Odom Cons. Engr., Baton Rouge, La.

explain the failure of the Mississippi River channel to deteriorate. It seems quite possible that flow past Red River Landing has not as yet been decreased sufficiently to permit channel deterioration, or that the decrease in flow passing Red River Landing has not been maintained for a period long enough to permit channel deterioration.

The Atchafalaya River has shown a marked increase in efficiency from 1920 to 1945, but the total quantity of flow passing Red River Landing has not as yet shown any marked or long continued decrease (see Fig. 8). A comparison of Fig. 8 with Fig. 7 shows that there is no trend apparent at Red River Landing which might not be considered equivalent to "normal" annual variation.

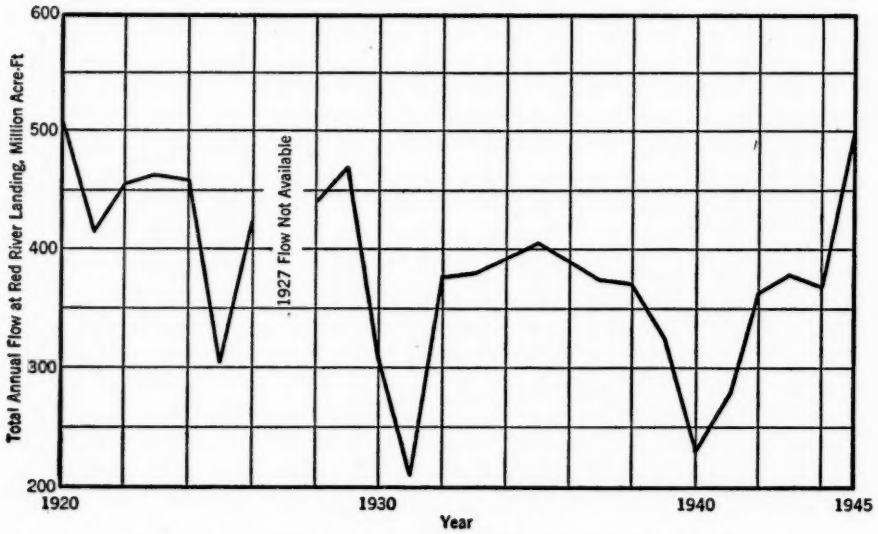

FIG. 8.—TOTAL ANNUAL FLOW PASSING RED RIVER LANDING, IN LOUISIANA

The 1920–1945 period also includes major floods which, through scour, doubtless served to retard any channel deterioration in the Mississippi which might have taken place. It is significant that the trend toward channel deterioration at Red River Landing, as shown in Fig. 4, reversed itself in about 1927. Even the 1927 flood might have resulted in a minor break in the trend line had it not been followed by a large total flow in 1928, and then the 1929 flood. Breaks traceable to the large 1935 flow, the 1937 flood, and the Smithland Reach dredging are also apparent in Fig. 4.

The author has suggested the diversion of sediment at the mouth of Old River as a clue to the failure of the Mississippi River channel to deteriorate as flow diversion increased. This clue should be subjected to further analysis if an understanding of Atchafalaya diversion is to be attained. It is believed that, to a large extent, the sediment diversion characteristics at Old River will govern the rate at which any channel deterioration might take place.

Data on sediment movement in a stream as large as the Mississippi River are difficult to obtain, and once obtained are of doubtful value. The only

attempt known to the writer to measure sediment in the Mississippi River in the vicinity of Old River was made in 1929 under the direction of the Mississippi River Commission.[27]

Two discharge ranges on the Mississippi River were selected as sampling ranges—one at Tarbert's Landing, which in 1929 was about $3\frac{1}{4}$ miles above the mouth of Old River; and one at Red River Landing about $1\frac{1}{4}$ miles below the mouth of Old River. Eight points at approximately equal intervals across the stream's width were selected as sampling stations. Three samples were obtained at each station—one sample at the surface, one at middepth, and one at the bottom. Samples were secured by a standard Mississippi River Commission "slip bottle" sampling device, consisting essentially of a hollow iron cylinder, 6 in. high and 8 in. in diameter, closed at its upper end and sliding on a vertical steel rod. Two steel disks are fixed on the vertical rod at a distance apart equal to the height of the cylinder. As the device is lowered to the sampling point the cylinder is in a raised position so that the upper disk seals the cylinder. Once the sampler has been placed the cylinder is dropped so that the bottom disk forms the seal, the water and sediment sample being trapped within the cylinder.

Samples obtained at each range were combined into three composite samples —one composite sample for the surface, one for the middepth, and one for the bottom. Analyses were run to determine the sediment concentration in each composite sample and the total sediment load was then computed.

The reliability of the data obtained by the method of sampling and analysis just outlined is open to question. It is believed, however, that these data should at least be indicative of the action taking place.

As shown in Table 11 there is a considerable variation in the quantity of sediment recorded from day to day at each station. There is an even more marked difference between the quantity of sediment observed at the Tarbert's Landing range and that observed at the Red River Landing range.

Day-to-day variations or even minute-to-minute variations in the sediment load at either discharge range might preclude the value of these data were it not for the fact that marked trends are apparent.

An inspection of Table 11 will show that there is apparently no relation between the quantity of water diverted and the quantity of sediment diverted. In one instance there was even an increase in the total sediment observed at Red River Landing over that observed at Tarbert's Landing. A close inspection of Table 11 will reveal that in all instances where there was a large concentration of sediment in the bottom sample there was a large apparent sediment diversion. This trend is presented graphically in Fig. 9.

The data presented in Table 11 and in Fig. 9 indicate that the diverted water is drawn largely from the lower part of the stream cross section. These data offer a considerable degree of support to the view expressed by the author and based solely on laboratory experiments.

Sediment obtained with a "slip bottle" sampler is probably suspended sediment. It is the writer's belief that very little, if any, bed-load material

[27] "Sediment Investigations on the Mississippi River and Its Tributaries Prior to 1930," *Paper H*, U. S. Waterways Experiment Station, Vicksburg, Miss., July, 1930.

would be obtained with the sampling device and methods used in the study described in the foregoing paragraphs. Even if a sample containing bed-load material were obtained in the stream thalweg, where the largest bed load would probably be found, its significance would be obscured by the compositing of all bottom samples.

If it is admitted that the data presented in Table 11 and Fig. 9 are applicable to the suspended sediment rather than to the total sediment load, the author's statement concerning the nature of the diverted material may be questioned.

TABLE 11.—COMPARISON OF SEDIMENT LOADS, RED RIVER LANDING AND TARBERT'S LANDING, IN LOUISIANA[a]

Date (1929)	Red River Landing gage,[b] (ft)	Parts Sediment per 100,000 Parts of Water, Tarbert's Landing			Sediment Discharge (Lb per Sec)		Water discharge Tarbert's Landing (1,000 cu ft per sec)	Apparent Percentage Diversion[c]	
		Surface	Mid-depth	Bottom	Tarbert's Landing	Red River Landing		Sediment	Water
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
March 23..	41.4	53.2	69.2	108.2	54,763	32,517	1,171	40.7	19.4
March 28..	44.5	41.6	54.8	58.6	40,823	25,796	1,248	36.8	18.4
March 30..	44.5	44.8	50.4	56.0	39,265	28,401	1,248	27.6	18.4
April 3....	46.7	34.5	50.3	55.1	38,260	27,504	1,288	28.0	12.7
April 9....	47.4	26.0	30.2	34.0	25,917	20,337	1,379	21.5	21.8
April 13...	48.1	28.3	32.4	37.0	28,120	21,170	1,385	24.7	20.5
April 16...	48.4	30.2	32.0	46.4	30,662	24,556	1,395	19.9	20.6
April 20...	49.0	31.8	36.4	35.4	31,123	24,555	1,424	21.1	20.8
April 23...	49.4	34.6	40.2	42.6	35,371	23,903	1,438	32.5	20.5
April 27...	49.7	32.2	36.6	41.6	33,304	26,354	1,454	20.8	21.4
April 30...	49.8	31.2	32.6	52.6	33,800	19,064	1,455	43.7	21.1
May 4.....	49.9	21.2	22.2	27.4	21,174	21,644	1,462	2.2	21.4
May 7.....	49.8	35.4	38.0	39.0	33,826	25,774	1,441	23.8	22.1
May 11....	49.7	28.2	40.2	37.7	32,446	30,606	1,420	5.7	19.5
May 14....	49.4	30.6	35.4	56.2	34,387	23,464	1,398	31.8	19.5
May 22....	49.7	27.2	37.9	37.2	30,503	25,567	1,396	16.2	19.7
May 24....	49.9	30.0	32.4	139.2	50,103	26,665	1,372	46.8	17.9
May 28....	50.5	31.6	42.2	49.8	38,572	30,349	1,489	21.2	21.9
June 3.....	51.8	32.4	36.2	46.0	36,002	27,954	1,530	22.3	24.0
June 8.....	52.3	24.0	30.0	37.8	29,810	27,669	1,565	7.2	20.9
June 18....	52.0	19.8	20.3	26.6	19,144	17,508	1,407	8.6	19.9

[a] "Sediment Investigations on the Mississippi River and Its Tributaries Prior to 1930," *Paper H*, U. S. Waterways Experiment Station, Vicksburg, Miss., July, 1930, pp. 59–60. [b] Bankfull stage is 43 ft. [c] Calculated from the difference in observed discharges at Tarbert's Landing and Red River Landing.

The following statements are quoted from the paper (under the heading, "Diversion of Sediment at a Channel Bifurcation"):

> "It should be clearly understood that material deposited (and carried through) the side channel is of bed-load nature. Material in suspension has been proved by the aforementioned [laboratory] investigators to divide in a ratio commensurate with the division of flow."

These statements may be quite true for laboratory channels in which a uniform suspended sediment distribution may be approached, but no relation between the quantity of suspended sediment diversion and the quantity of flow diversion is evident in Table 11. The division of suspended material is dependent on its distribution at the point of diversion. Laboratory investigations

notwithstanding, there are at present no methods for predicting, accurately, the distribution of suspended sediment in the cross section of a river; nor may the division of suspended load at the point of diversion be predicted.

If suspended sediment in the lower part of the stream cross section is diverted, it seems self-evident that most of the bed load will be diverted. Although the writer knows of no successful measurements of bed-load movement in natural streams, it seems reasonable to believe that at certain river stages the bed load will comprise a substantial part, if not the larger part, of the total sediment load.

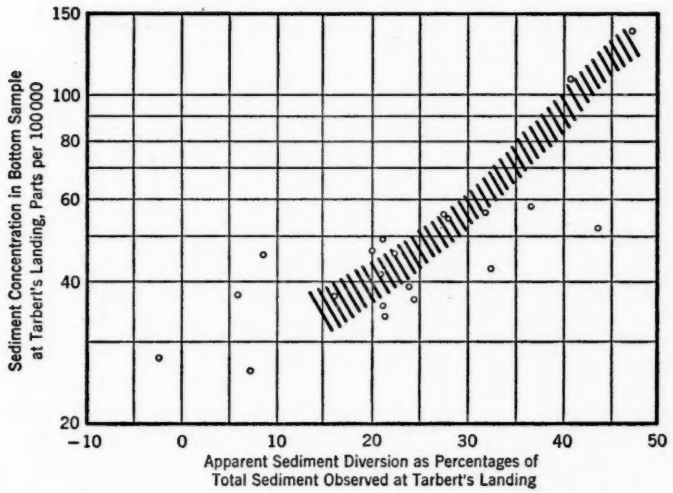

FIG. 9.—RELATION BETWEEN SEDIMENT DISTRIBUTION AND SEDIMENT DIVERSION AT TARBERT'S LANDING, IN LOUISIANA

Another factor that should not be overlooked in considering the effect of sediment diversion at Old River is the influence exerted by the decrease in flow reaching the Mississippi from Red River. The Red River carries an extremely high sediment load during high water. For example, at Alexandria, La., on December 13, 1930, a sediment discharge of 19,830 lb per sec was observed at a water discharge of 62,300 cu ft per sec.[28] Although this value is the maximum observed sediment load and discharge during about a one-year period when observations were made every second or third day, it is interesting to note that the maximum observed sediment load at Red River Landing on the Mississippi during the same high-water period was only 23,377 lb per sec at a discharge of 281,000 cu ft per sec.[29]

The channel of the Mississippi below Old River was formed by a stream carrying not only the total sediment load of the Mississippi River, but also the total sediment load of the Red River. The fact that development of the

[28] "Sediment Investigations on the Mississippi River and Its Tributaries, 1930–31," *Paper U*, U. S. Waterways Experiment Station, Vicksburg, Miss., December, 1931, p. 87.

[29] *Ibid.*, p. 22.

Atchafalaya has eliminated the Red River as a source of sediment for the Mississippi downstream from Red River Landing will certainly emphasize any effects which might be realized from the diversion of sediment at Old River.

Diversion of sediment at Old River is believed to be a major factor affecting the stability of the Mississippi River channel below Red River Landing. It must be realized, however, that the sediment diversion characteristics are continually changing. The failure of the Mississippi River channel to deteriorate between 1927 and 1945 indicates that the sediment diversion occurring at Old River during that period was such that the competence of the Mississippi River below Red River Landing was not overtaxed. Apparently enough sediment was removed at Old River to permit the remaining sediment load to be carried to the sea by the remaining water quantity without general deposition.

Such a condition should not be expected to be permanent, however. As an extreme example of what might eventually occur, it is conceivable that in time most of the sediment load of the Mississippi River will be "diverted" to the Mississippi, whereas the major part of the flow may be carried by the Atchafalaya. Under this condition the failure of the Mississippi River channel to deteriorate would be quite surprising.

It is the writer's belief that in the application, or contradiction, of the Guglielmini theory first importance should be attached to the nature and quantity of the stream's sediment load. Although the nature and quantity of a stream's sediment load is by no means a determinate problem, without its study there can be no logical approach to the diversion problem.

The Mississippi River below Old River was formed by a stream carrying the water and sediment load of the Mississippi and Red rivers. Diversion through the Atchafalaya has apparently resulted in the loss of a large part of the total sediment load as well as a considerable part of the water load. At present the diversion of sediment has occurred in sufficient quantity to prevent long-term channel deterioration in the Mississippi. It is believed that subsequent developments will depend on the variations in the ratio of water and sediment diversion and the occurrence of "abnormal" river flows, such as floods or very ow water.

Mr. Odom states that the channel of the Mississippi River below Old River is much more stable than in its upper reaches (under the heading, "Geology of the Lower Mississippi and Atchafalaya Rivers")—

> "The channel is narrower and deeper, high-water slopes are much less, and the bed materials are much more resistant to erosion [than in the upper reaches]."

The author further states, with regard to the Atchafalaya, that:

> "* * * it flows through erodible material and its average cross section throughout its leveed length has been constantly increasing for many years. This enlargement of the leveed channel has been accompanied by the silting up of the lakes and swamps between the ends of the leveed channel and the lower end of the basin."

Any marked variation in the nature of the bed materials at corresponding latitudes on the Atchafalaya and Mississippi rivers is somewhat surprising.

Both streams flow through the deltaic plain of the Mississippi and Red rivers and the areas traversed by both rivers are of similar if not identical geologic origin.

Also, it is believed that the significance of the erodibility of a particular bank material is somewhat obscured when considering the characteristics of the Atchafalaya River. Erodibility at the site is dependent on many other factors as well as on the nature of the bank material.

The upper Atchafalaya is in an early stage of geologic development. The water surface slopes are greater than is necessary to carry the stream's water and sediment load to the sea, and scour and channel enlargement result. This condition has been emphasized by the construction of levees, which serve to increase the water surface elevations, concentrate the current, and raise water surface slopes.

In the lower Atchafalaya, downstream from the ends of the levees, water surface slopes are insufficient to carry the sediment load and large-scale deposition results. Natural channels in the lower basin exhibit a braided stream pattern, and fill rather than scour generally occurs.

The Mississippi River downstream from Old River (as stated by the author) is in a poised condition. Its slope has been so adjusted that no general fill or scour takes place. Its relative stability in comparison with the Mississippi above Old River is doubtless due, in a large part, to the fact that the bank materials on the lower river are very resistant to erosion, but the effect exerted by the sediment diversion at Old River should not be overlooked. The relatively low sediment load presumably existing downstream from Old River would serve to deprive the Mississippi of material which might be used to initiate bed changes.

The Atchafalaya River and its relation to the Mississippi afford a rigorous testing ground for many of the theories of alluvial rivers. Mr. Odom has rendered a valuable service in presenting such a comprehensive study.

Leo M. Odom,[30] M. ASCE.—The material presented in this paper was accumulated while the writer was chief engineer of the Department of Public Works of Louisiana. The contents were drawn from a much more comprehensive study which was made to obtain "ammunition" for convincing Congress that the diversion from the Mississippi River into the Atchafalaya River should be controlled. This effort was made because of the great increase in capacity of the Atchafalaya River which was indicated by the flood of 1945. That flood caused the writer to reach the decision that it was time to do something about the diversion before the Atchafalaya actually replaced the Mississippi as the main stream.

The writer would have been happy to have offered the loss of capacity of the main river as an argument for control of the diversion, and it was while investigating this possibility that he came to the conclusions set forth in the paper.

Mr. Salisbury states that the velocity below the diversion is less than the velocity above and that, therefore, a portion of the silt load is deposited down-

[30] Cons. Engr., Baton Rouge, La.

stream. It is true that the measured velocity at Tarbert's Landing discharge range (mile 304.1 AHP) above Old River is nearly always greater than it is at the Red River Landing range (mile 299.5 AHP) immediately below Old River. This relation was obtained throughout the rise and fall of the major flood of 1945 or until the diversion through Old River dropped below 100,000 cu ft per sec. Had the velocity at Red River Landing not remained less than that at Tarbert's Landing during the time when Old River was diverting nearly 25% of the flow of the Mississippi above, the automatic adjustment in cross section posited by Mr. Salisbury would have been easier to visualize. Reduction in discharge accompanied by reduction in velocity does not indicate a reduction in cross section.

As proof of his contention of automatic adjustment in cross section at Red River Landing due to the diversion, Mr. Salisbury gives several readings of the gage and discharge measurements taken during the 1945 flood. It is to be noted that the first two measurements given in Table 7 were taken on a rising river and the latter two on a falling river. The writer has tried a similar comparison for the same flood using the records of the Natchez (Miss.) gage and readings taken near bankfull at Natchez (mile 359.2 AHP), at about the same time that the readings at Red River Landing were taken in Table 7. Table 12 indicates a variation of 8.3 ft for the Natchez gage at the same discharge. (The first two measurements were on rising stages and the last one on the falling stage.)

A check of several gages farther upstream will reveal that, in the 1945 flood, the elevation for approximately bankfull discharge at those gages was from 6 ft to 9 ft greater on the falling stage than on the rising stage.

TABLE 12.—READINGS AT NATCHEZ GAGE, TO BE COMPARED WITH THOSE IN TABLE 7 FOR RED RIVER LANDING

Date (1945) (1)	Gage height, in ft (2)	Mean velocity, in ft per sec (3)	Discharge, in thousands of cu ft per sec (4)
March 9...	41.1	6.33	1,329
March 12..	43.2	6.54	1,326
May 14 ...	49.4	5.71	1,328

Gerard H. Matthes,[31] Hon. M. ASCE, notes this phenomenon in his paper on Mississippi River cutoffs, using only the rising stages in comparing the effects of cutoffs. In this connection, he states that reductions in channel capacity of from 200,000 cu ft per sec to 250,000 cu ft per sec were found between rising and falling stages and he attributes this fact to the building up of the crossing bars. Since reduction in capacity between rising and falling stages is as great (possibly greater) at stations far removed from diversions as it is at Red River Landing this fact could scarcely be attributed to the diversion at Old River.

With reference to Mr. Salisbury's conclusion that the Red River Landing range lost cross-sectional area during the last 5 ft of rise because of the diversion, it is noted that many other stations on the river exhibited similar loss of cross-sectional area. At Natchez, in 1945, the cross section on the rising river at a gage reading of 50.8 was 233,100 sq ft, whereas at a gage reading of 55.2 it was 227,200 sq ft. The long flood of 1929 (during which overbank stages lasted

[31] "Mississippi River Cutoffs," by Gerard H. Matthes, *Transactions*, ASCE, Vol. 113, 1948, pp. 35–36.

for 102 days at Red River Landing) had several minor crests, and the cross sections at most stations on the river varied considerably for equivalent gage heights. Unfortunately the Natchez discharge measurements are very scanty for that flood. The Vicksburg station records of the first rise, for a gage height of 49.3, show a cross section of 219,000 sq ft whereas on the same rise, for a gage reading of 52.7, the cross section was 217,700 sq ft.

The absence of a long-term trend toward loss of cross section at the Red River Landing range is shown by the fact that, on the rise of the 1927 flood, the cross section at a gage reading of 47.8 was 225,200 sq ft, whereas at 47.4 on the gage in 1945, the cross section was 229,000 sq ft.

The reasons for changes in cross section during floods are numerous. During 1945 the right bank below Old River was caving rapidly and adding a great burden to the river at the Red River Landing range. This caving was greatest on the rise. Sand waves along the bottom of the river are said to cause the lessening of the cross section during their passage. The study of sand movements made in 1880–1881 at Plum Point reach (report of the United States Mississippi River Commission, November 25, 1881) revealed sand wave crests as high as 13 ft above the channel bottom. The diversion may have had some effect but the data seem to be very inconclusive.

Mr. Salisbury apparently would prefer to have Old River controlled by an overbank floodway. This possibility was discarded because the cities along the southern rim of the Atchafalaya Basin depend on the low-water diversion from the Mississippi River for their water supply since the low-water flow of Red River alone is negligible. It was also feared that, if the flow in the Atchafalaya River was restricted for long periods of time to volumes that reached its head from Red River, the latter (which is a much greater silt carrier than the Mississippi) would succeed in partly filling the channel of the Atchafalaya with silt. When the Atchafalaya River was needed for a relief outlet for the Mississippi River, it would then be incapable of furnishing the required capacity. The present project for closure of Old River provides for year-round diversion of flow but would control the flow by a fixed weir, at a low elevation, for stages below dangerous flood heights and would furnish movable gate control for overbank flows when the Mississippi required relief.

Mr. Higgs presents data on sediment measurements which were available to the writer when his study was made. The writer did not note any particular tendency from his study of these data and is glad that Mr. Higgs was able to determine that the sediment measurements bear out his more theoretical conclusions. Mr. Higgs' suggestion that the fact that Red River no longer flows into the Mississippi at any stage except the very lowest stages, and that this fact has changed conditions in regard to silt load below Red River Landing, is of interest. However, this condition has existed for a long time. The maximum discharge of Red River was about 250,000 cu ft per sec in 1945, whereas the maximum measured discharge of the Atchafalaya was 661,000 cu ft per sec. Mr. Halsey's discussion contains data about the growth of the Atchafalaya River which show that the Atchafalaya has long had a much larger capacity than the Red River.

Mr. Higgs is correct in his statement that, unless enlargement of the Atchafalaya River is controlled, it will become the main channel and that the Mississippi will become the diversion channel. At that time, the Mississippi will lose capacity rapidly.

There is no great variation in bank and bed materials between the Atchafalaya River and the Mississippi River below Red River Landing as Mr. Higgs points out. In fact, the Atchafalaya bed and banks are tougher. The bed and banks of both rivers are erodible, as is easily seen from inspection. The writer merely pointed out that the banks of the Lower Mississippi are tougher than those found farther upstream.

Mr. Halsey's discussion enlarges the scope of the paper and his critical investigation supports the assumptions made in preparing it. His extrapolations of the curves to include later data are welcome and his careful plotting of the trend lines, although it does not change the picture materially, has caused the writer to redraw them on his own copies of the exhibits.

Mr. Halsey's study of the cause of the divided channel at Smithland, and subsequent loss of capacity there until the corrective dredging was done, adds to the value of the paper. His discussion of the enlargement of the Atchafalaya River and the relative danger of its capture by the Mississippi River is outside the scope of this paper and a complete analysis of his conclusions in this regard would require more space than is available. However, the writer has studied this problem in considerable detail. Mr. Higgs gives a brief statement as to the forces involved with which the writer agrees. The enlargement of the Atchafalaya River has progressed downstream as its levees were extended. The soil in its basin is composed of clays, silts, and sands.

Enlargement of its cross section by scour was great where sands were encountered, so that extreme depth was also accompanied by abnormal width. As the scour progressed, clay blankets in the bed above and below the large holes were undermined. The channel was formerly a succession of large holes and smaller reaches. Flow was very turbulent, therefore, and the great loss of energy was reflected in the fact that a much higher roughness factor is indicated than is usual for a stream of its size. The dredging by the United States Mississippi River Commission in the early 1930's was done for the purpose of improving the discharge capacity by dredging through a great many of the clay layers in the bed. Once the alternate hole and choke pattern was broken up, the river did as was expected and filled the larger holes to some extent while it enlarged the choke sections. The capacity was greatly improved—much more than the growth in average cross section would indicate.

In the earlier stages of development of the Atchafalaya River most of the enlargement occurred at the upper end. The upper 3 miles had an average bankfull cross section of 58,000 sq ft as compared to an average of 15,000 sq ft for the lower 5 miles and an average of 44,000 sq ft for the entire 58.0 mile-length of the main river. In later years the locus of maximum enlargement has shifted to the lower end. After the 1945 flood, the upper 3 miles had an average cross section of 88,200 sq ft as compared to 72,400 sq ft for the lower 5 miles and an average throughout the entire length of 79,800 sq ft.

Prior to the 1945 flood the gain in discharge capacity and the gain in cross section had increased with each major flood; but the increase had been relatively slow and, if the average cross-sectional areas for the stream were plotted against the years, a straight line would closely approximate the increase. A straight-line relationship also applied to the bankfull and overbank discharges. However, the 1945 flood caused enlargements which departed greatly from the previous straight-line development and the discharge increased in an even greater proportion. Prior to 1945 the responsible authorities had concluded that the enlargement would proceed at the relatively uniform rate which had been in vogue for 40 years. With that rate of increase, it would have taken many years for piracy of the Mississippi to be threatened. The U. S. Mississippi River Commission, in formulating its flood control program, needed considerably greater high-water discharge down the Atchafalaya than was occurring and much time lapse seemed likely before the desired cross section would be developed. The large jump from the straight-line increase during the 1945 flood resulted in seeking Congressional authorization for control works.

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